MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2015/2016

EME2146 – APPLIED THERMODYNAMICS
(ME)

12 OCTOBER 2015
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of six pages (including the cover page) with four questions and an Appendix.
2. Answer ALL four questions.
3. Each question carries 25 marks and the distribution of the marks for each question is given in brackets [ ].
4. Write all your answers in the answer booklet provided.
5. A property table booklet is provided for your reference.

Question 1

A rigid tank contains a non-reacting mixture at 100 kPa and 90 °C. The mixture consists of 560 g of nitrogen gas (N_2), 320 g of oxygen gas (O_2), 2200 g of carbon dioxide gas (CO_2), and 90 g of water vapor (H_2O). Assuming ideal gas behavior of the gaseous mixtures and taking the universal gas constant, $R = 8.314$ J/mol·K, determine

a. the mass fraction of each component,

[4 marks]

b. the number of mole of each component,

[4 marks]

c. the total number of mole of the mixture,

[3 marks]

d. the mole fraction of each component,

[4 marks]

e. the absolute humidity of the mixture,

[3 marks]

f. the relative humidity of the mixture, and

[4 marks]

g. the dew point temperature of the mixture.

[3 marks]

Continued...

Question 2

Butane gas (C_4H_{10}) is supplied to a combustion chamber at a constant rate of 116 g/s. It is mixed with 100 % excess air (dry air) at same the temperature of 25 °C. The mixture is combusted completely at the constant pressure of 100 kPa. The product gases of combustion exit the chamber at 727 °C. Assume ideal gas behavior of the gaseous mixtures, and taking the universal gas constant, $R = 8.314$ J/mol·K.

a. Find the balanced combustion equation.

[6 marks]

b. Calculate the air-fuel ratio.

[3 marks]

c. Determine the rate of heat transfer from the combustion.

[8 marks]

d. Find the dew-point temperature of the product gases.

[3 marks]

e. Calculate the amount of water vapor (in kg) that condensed after 10 minutes if the product gaseous are cooled to 10°C at 100 kPa .

[5 marks]

Continued...

Question 3

A commercial jet engine produces work at the rate of 8.5 MW to cruise the aircraft at the constant speed of 500 km/hour. The jet engine is assumed to operate on an ideal Brayton cycle. Air and fuel are mixed and enter the engine at the atmospheric conditions, 100 kPa and 27 °C. The air-fuel mixture is flowing constantly through the engine at the rate of 20 kg/s. The compression ratio of the compressor is 1.5^7. Assume constant specific heat, $c_p = 1.00$ kJ/kg·K and specific heat ratio, $\gamma = 1.4$.

a. Sketch and label the $T - s$ diagram of the cycle.

[3 marks]

b. Sketch and label the $p - v$ diagram of the cycle.

[3 marks]

c. Find temperature after compression.

[3 marks]

d. Determine the maximum temperature of the cycle.

[5 marks]

e. Find the exit temperature of the exhaust gases.

[3 marks]

f. Determine the thermal efficiency of the cycle.

[5 marks]

g. Find the thrust force produced by the engine at this instant.

[3 marks]

Continued...

Question 4

A well-insulated and frictionless piston cylinder system contains a gaseous of a pure substance and is expanded from the initial volume, v_i to the final volume, v_f as shown in Figure Q4.

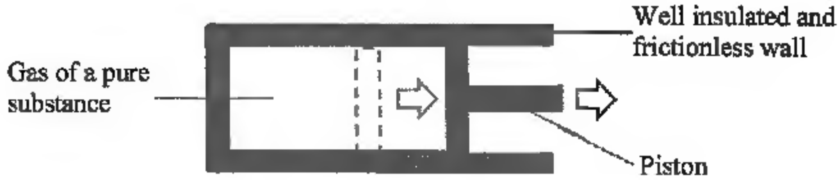

Figure Q4

The equation of state of the pure substance can be described by expressing the compressibility factor, z, in terms of the converged virial series:

$$z = \frac{pv}{RT} = \sum_{n=0}^{\infty} \frac{K_n(T)}{v^n}$$

where the virial coefficients, $K_n(T)$ are temperature dependent and the coefficient of the first term, $K_0 = 1$, R is the universal gas constant, v is the specific volume, $v \neq 0$, and n is an integer. Assume constant specific heats, c_p and c_v.

a. Show that the adiabatic expansion process of an ideal gas can be expressed with the pressure and volume relation, $pv^{\gamma} = \text{constant}$, where γ is the specific heat ratio.

[9 marks]

b. Sketch the process in part (a) on the $p - v$ diagram in comparison with the isothermal expansion process.

[4 marks]

c. Show that the temperature at the final state under the adiabatic expansion is lower than the isothermal expansion.

[4 marks]

d. Determine the pressure and volume relation for an adiabatic expansion process if the substance is assumed to satisfy the virial equation of state where the term containing v^{-2} is very small and can be neglected. Under the particular range of pressure and temperature, the viral coefficient, $K_1(T)$ can be assumed constant as K.

[8 marks]

Continued...

APPENDIX

A1. Clayperon Relation:

$$\frac{dp_{sat}}{dT} = \frac{s_{fg}}{v_{fg}} = \frac{h_{fg}}{Tv_{fg}}$$

A2. Maxwell Relations:

$$\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial p}{\partial s}\right)_v ; \quad \left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p$$
$$\left(\frac{\partial v}{\partial T}\right)_p = -\left(\frac{\partial s}{\partial p}\right)_T ; \quad \left(\frac{\partial p}{\partial T}\right)_v = \left(\frac{\partial s}{\partial v}\right)_T$$

A3. Change of internal energy, enthalpy, and entropy:

$$u_2 - u_1 = \int_{T_1}^{T_2} c_v dT + \int_{v_1}^{v_2} \left[T\left(\frac{\partial p}{\partial T}\right)_v - p\right] dv$$
$$h_2 - h_1 = \int_{T_1}^{T_2} c_p dT + \int_{p_1}^{p_2} \left[v - T\left(\frac{\partial v}{\partial T}\right)_p\right] dp$$
$$s_2 - s_1 = \int_{T_1}^{T_2} \frac{c_v}{T} dT + \int_{v_1}^{v_2} \left(\frac{\partial p}{\partial T}\right)_v dv = \int_{T_1}^{T_2} \frac{c_p}{T} dT - \int_{p_1}^{p_2} \left(\frac{\partial v}{\partial T}\right)_p dp$$

A4. Molecular weight of various substances

Substance	N_2	O_2	CO_2	CO	H_2O	C_4H_{10}	C
Molecular weight, g/mol	28	32	44	28	18	58	12

End of Paper